# FILM RIDING BRUSH SEAL PRELIMINARY STUDIES

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Brush seals can improve engine efficiency by inhibiting secondary flow leakage, bur rotor excursions produce wear that degrades performance. A brush seal combined with a film riding seal precludes brush wear, accommodates rotor excursions without rubbing contact and restricts leakage to lower values than contemporary brush seals. The function of the brush is to act as a secondary seal to limit the hydraulic closing load, and to provide radial resilience.

## Film Riding Brush Seal Preliminary Studies

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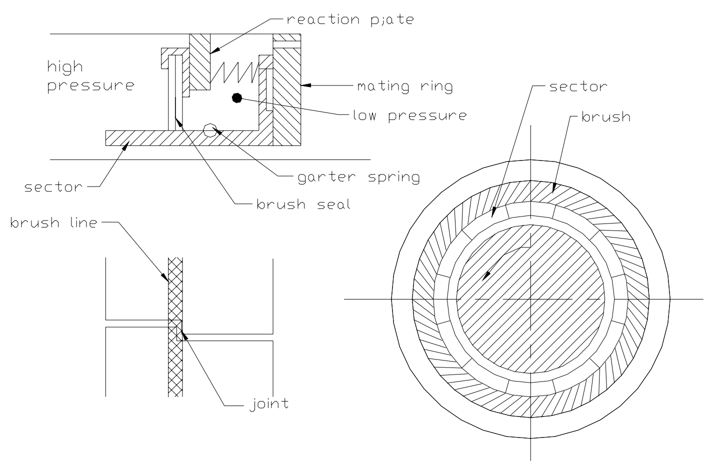
NASA Seal Workshop 2002

# Objectives

- Reduce brush wear
  - Eliminate interface rotation
- Reduce overall leakage
- Provide radial compliance

# FRBS Schematic

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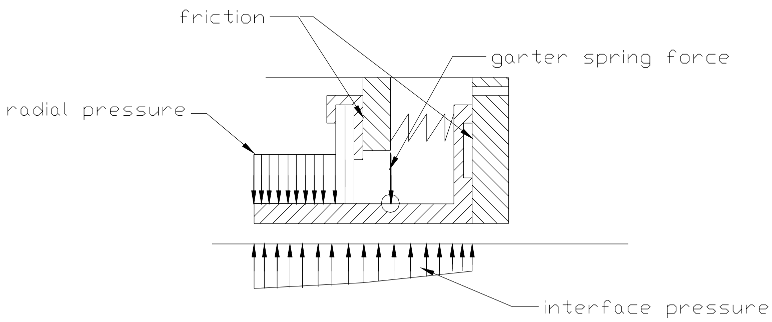
- L-shaped cylindrical sectors that mate against a housing
- Sealing occurs through radial clearance between sectors and shaft.
- Brush acts as secondary seal

# Radial Force Equilibrium

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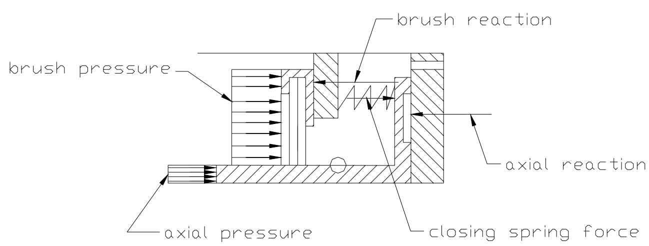
•Position of brush determines radial preload

•Friction can occur at brush interface, but radial compliance provided by bristles

# Axial Force Equilibrium

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•Reaction plate absorbs thrust from brush
•Axial spring  load used for force and moment balance

# Brush Functions

- Brush acts as secondary seal
- Position determines radial preload
- Brush provides radial compliance
- Brush supplies cooling flow
- Brush wear minimized- non-rotating interface

# Sectors

- Improves radial compliance
- Reduces thermal distortions
- Allows for small clearances
  - Can move relative to each other
- Improves dynamic response
  - Low mass



•Sectors should be as thin as possible to minimize axial loads

•Sectors can follow rotor excursions

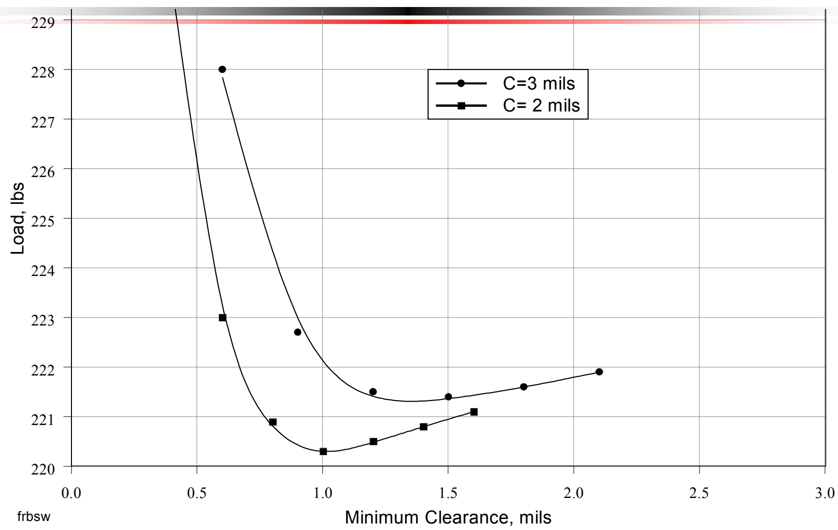
# Operating Parameters

| | |
|---|---|
| Diameter | 6.5 in. |
| Length | 2.5 in. |
| Pad Angle | 30 degrees |
| Viscosity | 4.32 x 10-09 reyns |
| Temperature | 600 F |
| Speed | 36,000 rpm |
| Press. Diff. | 100 psi |
| Clearance | 0.002, 0.003 |



•Examined a potential application

# Load Capacity

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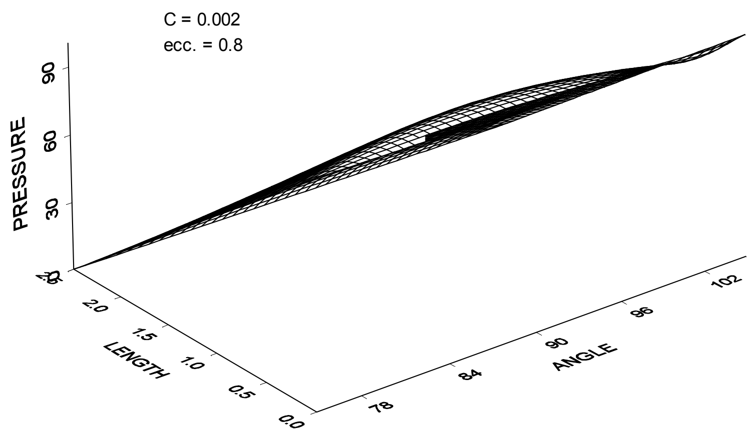
- Best to operate in steep portion of curve for maximum stiffness
- For c= 2 mils and a minimum clearance of o.5 mils, load capacity is 226 lbs.
- To obtain a balanced closing load, the brush would be located approximately 1.8 inches from the high pressure end

# Pressure Distribution

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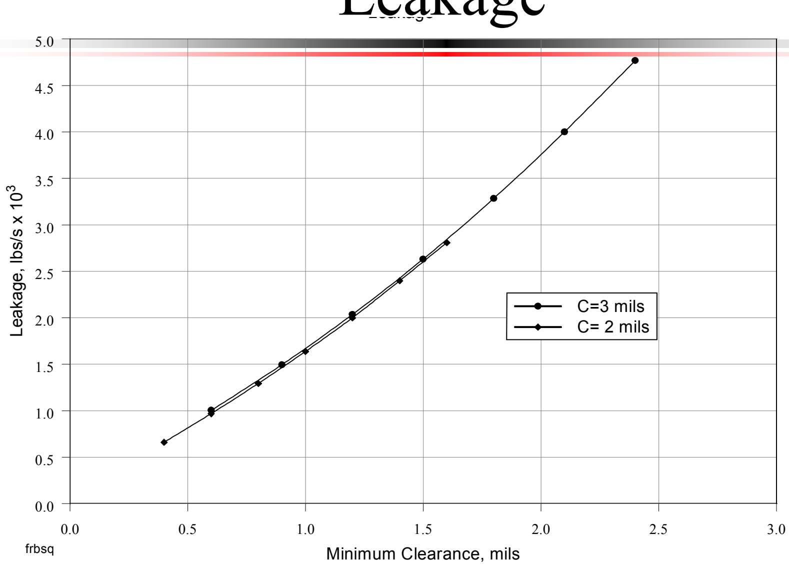
- The linear drop occurs with and without rotation
- The linear drop has zero stiffness
- The hump above is produced by hydrodynamic action and provides positive stiffness.
- Hydrodynamics may be improved by geometry, such as steps

# Leakage

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- Not much difference between 2 and 3 mils
- At 0.5 mils minimum clearance, leakage is 0.7 x 10e-03 lbs/s

# Flow Parameter

$$\phi = \frac{\dot{m}\sqrt{T}}{PD}$$

$$\phi = flow\ parameter$$

$$\dot{m} = mass\ \ flow, lbs / s$$

$$T = absolute\ temperature,\ ^{o}R$$

$$P = pressure\ differential,\ psi$$

$$D = diameter,\ in.$$



•Flow parameter is a measure of leakage characteristics

# Flow Parameter Values

$$\phi(brush) = 0.001(non-rotating)$$

$$\phi(film) = 0.0004(12\ sectors)$$

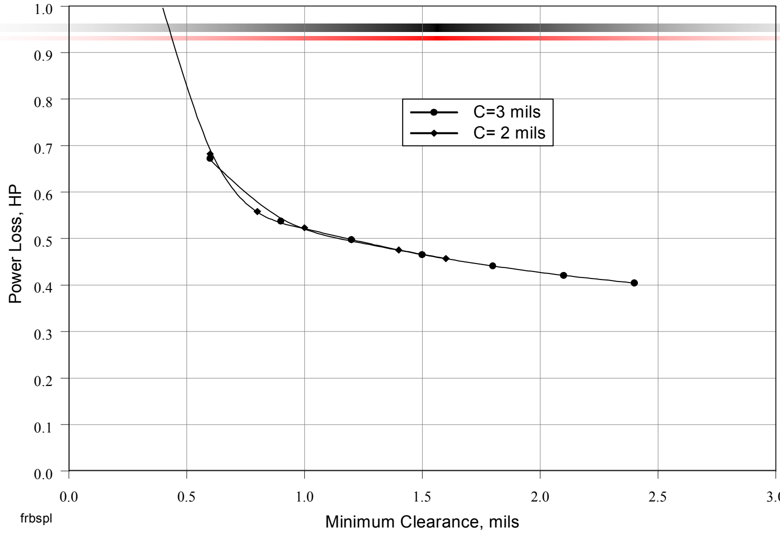
$$\phi(labyrinth) = 0.007$$

$$\phi(target) = 0.003$$



- Film flow parameter is very low
- Most leakage will occur across the brush
- Labyrinth flow parameter is much higher
- Additional flow will occur between sectors, but the target value should be readily attained

# Power Loss

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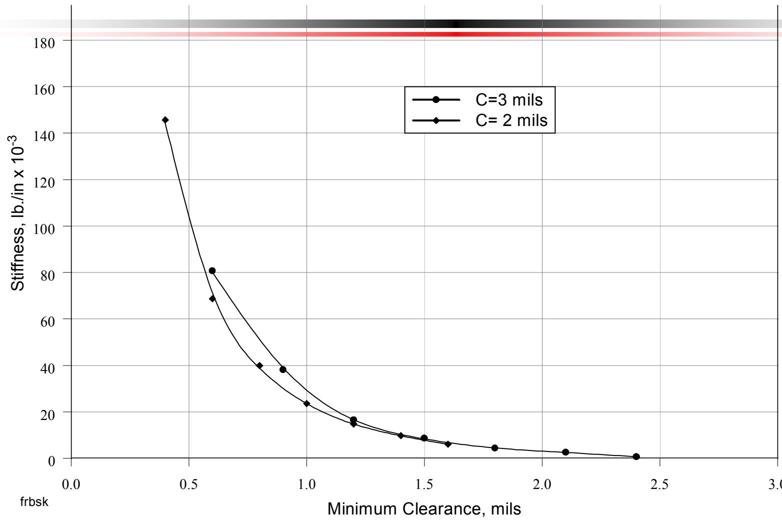
- Curve applies to a single sector
- Total Power loss is relatively high
- Heat generation is mitigated by brush cooling flow
- Sectors reduce distortions

# Stiffness

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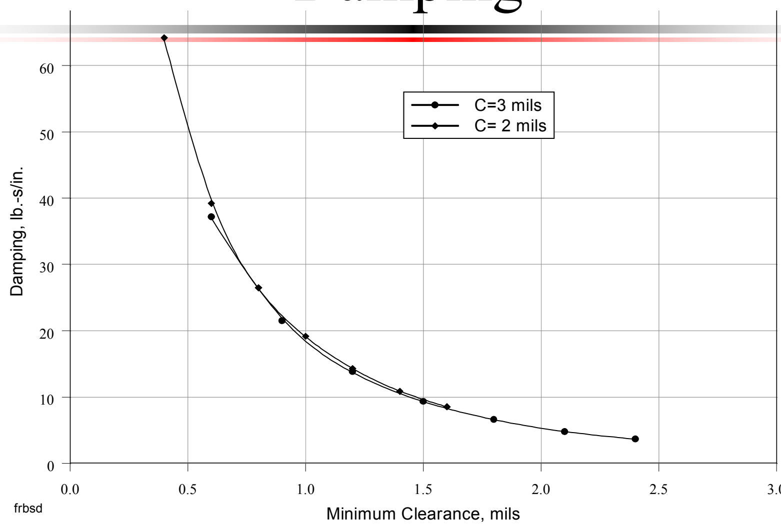
•At a minimum clearance of 0.5 mils , the stiffness is 100,000 lbs/in.

•The stiffness must be sufficient to overcome brush resistance, preload and friction.

# Damping

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•Damping at 0.5 mils clearance is 50 lb-s/in.

•Damping is relatively high so that squeeze-film can assist in preventing contact.

# Design Considerations

- Force and Moment Balance-including radial friction
- Brush stiffness
- Pad materials
- Pad clearance
- Pad preload
  - <=5psi
- Dynamic Response



•Sectors require a force and moment balance under all conditions of operation

•Brush stiffness must be less than film stiffness

•Pad materials must withstand high speed rubs

•Pad clearance and preload both effect performance and should be optimized

•Design should accommodate  large radial runouts, shock and vibration

# Potential Risks

- High-speed rubs
  - Appropriate materials must be determined
- Pad balance over operating range
- Excessive length
  - L/D>=1/3
- Heat generation
- Slow speed operation



•Slow speed reduces hydrodynamic capability

# Summary

- FRBS has potential but significant development is required
- Advantages include:
  - Reduced leakage
  - Reduced Brush wear
  - Radial compliance